Metacarpal Bony Dimensions Related to Headless Compression Screw Sizes

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Abstract

Introduction The purpose of this study is to determine the radiographic dimensions of the finger metacarpals and to compare these measurements with headless compression screws commonly used for fracture fixation.

Materials and Methods We analyzed computed tomography (CT) scans of the index, long, ring, and small metacarpal bones and measured the metacarpal length, distance from the isthmus to the metacarpal head, and intramedullary diameter of the isthmus. Metacarpals with previous fractures or hardware were excluded. We compared these dimensions with the size of several commercially available headless screws used for intramedullary fixation.

Results A total of 223 metacarpals from 57 patients were analyzed. The index metacarpal was the longest, averaging 67.6 mm in length. The mean distance from the most distal aspect of the metacarpal head to the isthmus was 40.3, 39.5, 34.4, and 31 mm for the index, long, ring, and small metacarpals, respectively. The narrowest diameter of the isthmus was a mean of 2.6, 2.7, 2.3, and 3 mm for the index, long, ring, and small metacarpals, respectively. Of 33 commercially available screws, only 27% percent reached the isthmus of the index metacarpal followed by 42, 48, and 58% in the long, ring, and small metacarpals, respectively.

Conclusion The index and long metacarpals are at a particular risk of screw mismatch given their relatively long lengths and narrow isthmus diameters.

Keywords
- headless compression screws
- metacarpal
- intramedullary
- anatomy
- computed tomography

Introduction

Metacarpal fractures account for 18% of upper extremity fractures.[1] Men sustain a substantially higher proportion of metacarpal fractures compared with women (76%), whereas the highest incidence is observed among the 15- to 35-year-old age group.[1,2] There are many fixation options available for the treatment of metacarpal fractures, including Kirschner wires, plates, wires, lag screws, and intramedullary headless compression screws (HCSs).[3,4] HCS fixation has an advantage of intramedullary, zero-profile, stable fixation with minimal soft tissue violation, which allows for early motion postoperatively. There are several manufacturers that provide HCS with different sizes, designs, and lengths for fixation. Knowledge of bony anatomy and available implants is important for operative planning and proper fixation.

We are not aware of any advanced imaging studies that compare intramedullary HCS dimensions with intramedullary metacarpal anatomy. The purpose of this study is to determine the dimensions of the finger metacarpals and to compare these measurements with HCSs commonly used for fracture fixation. We hypothesize that (1) anatomy will vary with age and sex and (2) there will be certain screws that do not fit the metacarpal anatomy.

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Materials and Methods

This study is a radiographic evaluation of 59 computed tomography (CT) scans of the hands of skeletally mature patients who presented to our clinic between 2010 and 2018. Metacarpals with any evidence of previous fractures, implanted hardware, bone or soft tissue abnormalities, and/or incomplete CT sequences were excluded from the study. Patients with a CT scan of the hand were included and reviewed.

All CT scans were measured using the Sectra IDS7 (Linköping, Sweden) diagnostic imaging platform set to a calibrated contrast and white balance and were reviewed by a fellowship-trained orthopaedic hand surgeon. Several parameters were measured by analyzing the CT scans of the index, long, ring, and small metacarpals: (1) diameter of the isthmus, defined as the narrowest diameter of the intramedullary canal in the axial bone windows, (2) distance from the distal most aspect of the metacarpal head to the isthmus proximally, and (3) metacarpal length and midshaft in the coronal bone windows (►**Fig. 1**). The last measurement was made using the localizer function to determine the corresponding location of the isthmus on the coronal bone window. This distance was then normalized for each bone by dividing this distance by the metacarpal length.

Commercially available HCS dimensions were compiled, including (1) leading thread (screw tip) diameter, (2) trailing thread (screw head) diameter, and (3) available lengths. The screws were chosen based on surgeon experience and the public availability of operative technique guides that contained the specifications of interest. We compared screw sizes with the bony anatomy of the metacarpal bones. We considered a screw to fit without reaming if the screw diameter of the leading threads was less than or equal to the narrowest measured canal isthmus diameter. Primary outcomes included the diameter of the isthmus, length of the isthmus to the distal most aspect of the metacarpal head, and percentage of bones with cortical contact with leading threads.

We calculated the number of screws that reached the metacarpal isthmus and the number that reached the midshaft. For the screws that reached the isthmus, we determined which screw engaged the inner cortex. For screws that reached the isthmus or midshaft, the range of available length past either point was also determined.

Differences between genders and between metacarpals were analyzed using independent sample *t*-tests. Differences within the same individual were analyzed using paired sample *t*-test. All advanced statistical analysis was performed using SPSS Statistics 25.0 (IBM, Armonk, New York, United States).

Results

Two of the CT scans were excluded altogether due to open physes, yielding 57 CT scans as the basis for this study. Among five of these CT scans, one index, one long, two ring, and one small metacarpals were excluded due to evidence of previous trauma, leaving a total of 56 index, 56 long, 55 ring, and 56 small metacarpals for analysis. The patient group included 41 men and 16 women, with an average age of 41.2 years

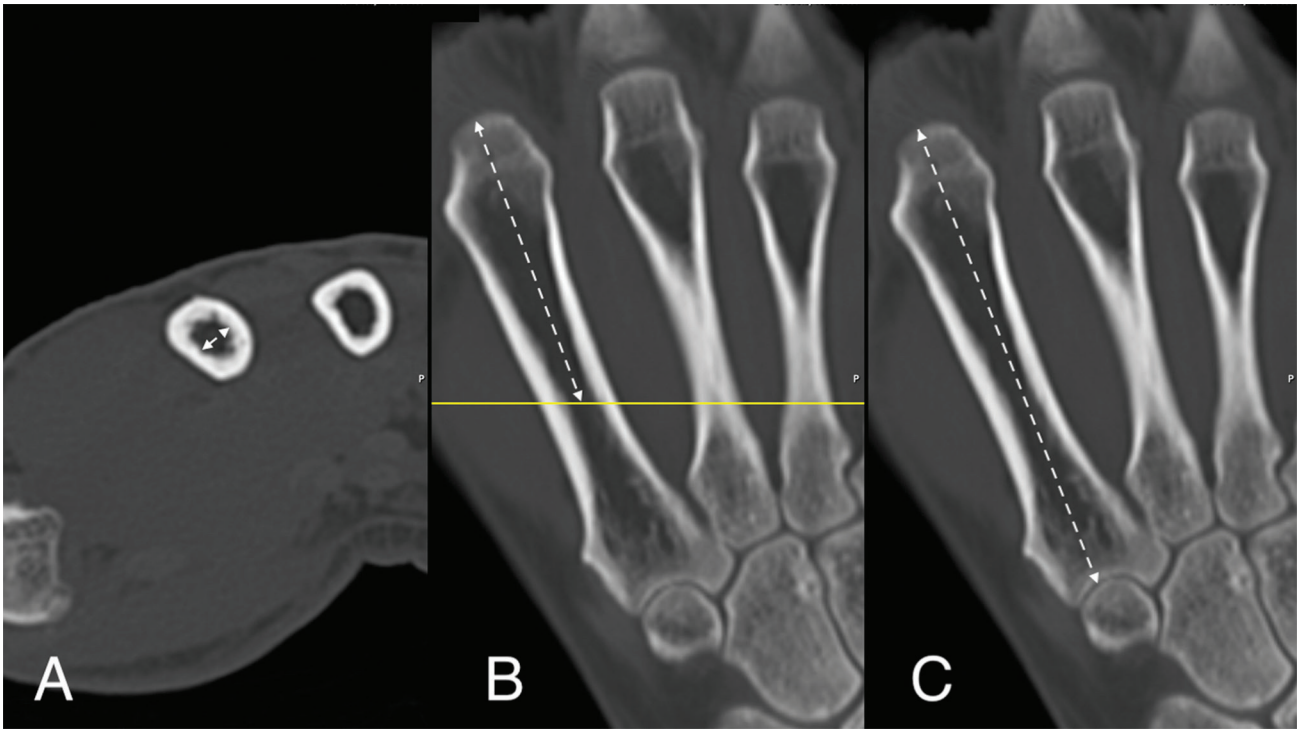

Fig. 1 Computed tomography (CT) scan showing measurements of the index metacarpal. The *yellow localizer line* shows depict the isthmus level on coronal views. (**A**) Diameter of the isthmus, defined as the narrowest diameter of the intramedullary canal in the axial bone window. (**B**) Distance from the distal most aspect of the metacarpal head to the isthmus proximally. (**C**) Metacarpal length in the coronal bone windows.

(range: 15–88 years). Each of the measurements was made on the 223 metacarpals for a total of 669 measurements.

►**Table 1** displays measurements and calculations for all patients. The index metacarpal was the longest on average at 67.6 mm followed by the long (65.6 mm), ring (57.8 mm), and small metacarpal bones (52.3 mm). The diameter of the isthmus was on average 2.6, 2.7, 2.3, and 3 mm for the index, long, ring, and small metacarpals, respectively. The average distance from the distal most aspect of the metacarpal head to the isthmus was 40.3, 39.5, 34.3, and 30.9 mm for the index, long, ring, and small metacarpals, respectively. When normalizing this distance by the metacarpal length, the isthmus was located on average 60% of the length from distal to proximal, a number which remained constant for all of the fingers (►**Fig. 1**).

Dimensions of 33 commercially available screws by eight manufacturers were compared with the metacarpal anatomy we measured. The leading thread diameter of these screws ranged from 1.7 to 4.5 mm, and the available lengths ranged from 8 to 110 mm (►**Table 2**). Of the 33 screws listed, only 27% of screws reached the isthmus of the index metacarpal followed by 42, 48, and 58% in the long, ring, and small metacarpals, respectively (►**Table 3**). Given that the isthmus location was more proximal to the metacarpal midshaft, a greater percentage of screws were able to reach the midshaft across all metacarpals (►**Table 3**). There were no screws that were undersized and reached in the index and ring metacarpal isthmuses; however, within our list, two (6%) and eight (24%) screws did not engage at the isthmus at the long and small metacarpals, respectively (►**Table 3**).

Pearson's correlation statistic for the isthmus diameter versus age was poor for the index (0.30), long (0.21), ring (0.22) and small metacarpals (0.12). Independent sample *t*-test showed sex differences in all anatomical measurements except the long isthmus diameter (2.8 mm in men vs. 2.6 mm in women), ring isthmus diameter (2.4 mm in men vs. 2.1 mm in women), and the ratio of the isthmus location to the length of the metacarpal bone in all metacarpals (0.6) (►**Table 4**).

Discussion

The use of HCSs for the treatment of metacarpal fractures has become more popular because they can allow for early mobilization, ease of exposure, and minimization of prominent hardware.[5,6] As such, our study goals were to describe metacarpal bony anatomy through CT scans and then relate sizes to commercially available headless intramedullary screws. Our results highlight that the index metacarpal is consistently longer than the long metacarpal despite the clinically longer appearing long or "long" finger. This finding is

Table 1 CT measurements of metacarpal bones

	N	Mean	SD	Min	Max
Age	57	41.2		15	88
Index isthmus diameter	56	2.6 mm	0.9	0.7	5.5
Long isthmus diameter	56	2.7 mm	1.0	0.8	5.6
Ring isthmus diameter	55	2.3 mm	0.8	0.7	4.3
Small isthmus diameter	56	3.0 mm	0.9	1.2	5.3
Index isthmus location	56	40.3 mm	4.1	27.7	48.7
Long distance to the isthmus	56	39.5 mm	4.2	31.0	47.7
Ring distance to the isthmus	55	34.4 mm	3.8	25.9	41.1
Small distance to the isthmus	56	31.0 mm	4.7	20.9	37.9
Index metacarpal length	56	67.6 mm	4.5	52.9	75.8
Long metacarpal length	56	65.6 mm	4.9	49.7	74.2
Ring metacarpal length	55	58.0 mm	4.1	43.8	66.4
Small metacarpal length	56	52.5 mm	4.1	40.7	59.4
Index isthmus location/MC length	56	0.6 mm	0.0	0.5	0.7
Long isthmus location/MC length	56	0.6 mm	0.0	0.5	0.7
Ring isthmus location/MC length	55	0.6 mm	0.1	0.4	0.8
Small isthmus location/MC length	56	0.6 mm	0.1	0.4	0.7
Index MC head to the midshaft	56	33.8 mm			
Long MC head to the midshaft	56	33.0 mm			
Ring MC head to the midshaft	55	29.0 mm			
Small MC head to the midshaft	56	26.2 mm			

Abbreviations: CT, computed tomography; MC, metacarpal; SD, standard deviation.

Table 2 Screw specifications

Implant	Leading thread diameter (mm)	Thread length	Length (mm)	
Acumed Acutrak Micro[a]	2.5	n/a	8	20
Acumed Acutrak Mini[a]	3.5	n/a	16	30
Acumed Acutrak Standard[a]	4	n/a	16	34
Acumed Acutrak Fusion[a]	2	n/a	14	24
Zimmer Mini Herbert[b]	2.5	Not stated	14	24
Zimmer Herbert 3.0[b]	3	Not stated	12	30
Zimmer HCS 4.5[b]	4.5	8.2, 12, 16.0 mm	25	100
ExsoMed Innate 4.0[c]	4	n/a	35	75
DePuy Synthes HCS 2.4 (ST)[d]	2.4	20% screw length	9	40
DePuy Synthes HCS 2.4 (LT)[d]	2.4	40% screw length	17	40
DePuy Synthes HCS 3.0 (ST)[d]	3	20% screw length	10	40
DePuy Synthes HCS 3.0 (LT)[d]	3	40% screw length	10	40
DePuy Synthes HCS 4.5 (ST)[d]	4.5	20% screw length	16	110
DePuy Synthes HCS 4.5 (LT)[d]	4.5	40% screw length	16	110
Stryker AutoFIX 2.0[e]	2	Not stated	10	30
Stryker AutoFIX 2.5[e]	2.5	Not stated	10	30
Stryker AutoFIX 3.0[e]	3	Not stated	12	60
Stryker AutoFIX 4.0[e]	4	Not stated	20	50
Stryker Fixos 2.5[e]	2.5	Not stated	10	30
Stryker Fixos 3.5[e]	3.5	Not stated	14	24
Stryker Fixos 4.0[e]	4	33% screw length	14	80
Skeletal Dynamics Reduct 2.5[f]	2.6	Not stated	10	30
Skeletal Dynamics Reduct 3.5[f]	3.4	Not stated	10	30
TriMed Cannulated Screw 1.7[g]	1.7	Not stated	8	14
TriMed Cannulated Screw 2.3[g]	2.3	Not stated	10	28
TriMed Cannulated Screw 3.0[g]	3	Not stated	10	36
TriMed Cannulated Screw 3.5[g]	3.5	Not stated	20	45
Arthrex Micro Compression FT 2.5[h]	2.5	n/a	8	30
Arthrex Mini Compression FT 3.5[h]	3.5	n/a	12	34
Arthrex Standard Compression FT 4.0[h]	4	n/a	16	50
Arthrex Headless Compression PT 2.5[h]	2.5	33% Screw Length	8	34
Arthrex Headless Compression PT 3.0[h]	3	33% Screw Length	10	36
Arthrex Headless Compression PT 4.3[h]	4.3	33% Screw Length	14	80
Range	1.7 - 4.5		8	110

Abbreviations: HCS, headless compression screw; FT, fully threaded; LT, long thread; PT, partially threaded; ST, short thread.
[a]Acumed (Hillsboro, Oregon, United States).
[b]Zimmer (Warsaw, Indiana, United States).
[c]ExsoMed (Aliso Viejo, California, United States).
[d]DePuy Synthes (Raynham, Massachusetts, United States).
[e]Stryker (Kalamazoo, Michigan, United States).
[f]Skeletal Dynamics (Miami, Florida, United States).
[g]TriMed Inc. (Valencia, California, United States).
[h]Arthrex (Naples, Florida, United States).

consistent with pervious cadaveric and radiographic studies looking at relative lengths of the metacarpal bones.[7-10] The index digit appears shorter as its metacarpal articulation with the carpus is more proximal as compared with the long metacarpal. The difference in metacarpal length between men and women is consistent with the literature on skeletal size and length.[7-9,11] The average retrograde ratio of the isthmus distance to the metacarpal length (0.6) was consistent

Table 3 Screw metacarpal size analysisa

	Index	Long	Ring	Small
Percentage of screws that reach the mid-shaft	19 of 33 (58%)	19 of 33 (58%)	27 of 33 (82%)	28 of 33 (85%)
Percentage of screws that reach the isthmus	9 of 33 (27%)	14 of 33 (42%)	16 of 33 (48%)	19 of 33 (58%)
Percentage of screws that reach the isthmus and do not engage the inner cortex	0 of 33 (0%)	2 of 33 (6%)	0 of 33 (0%)	8 of 33 (24%)
Screws that reach the midshaft, screw length past midpoint	20.1 mm (range: 0.2–76.2 mm)	20.9 mm (range: 1.0–77.0 mm)	17.8 mm (range: 1.0–81.0 mm)	19.9 mm (range: 1.8–83.8 mm)
Screws that reach the isthmus, screw length past isthmus	31.9 mm (range: 4.7–69.7 mm)	21.1 mm (range: 5–70.4 mm)	23.2 mm (range: 1.6–75.6 mm)	26.6 mm (range: 5.0–79.0 mm)

[a]Calculations made without assuming countersinking.

Table 4 Sex differences

	Sex	*N*	Mean	Standard deviation ($P < 0.05$)
Age	M	41	40.8	
	F	16	42.3	
Index isthmus diameter	M	40	2.7	0.8
	F	15	2.2	0.9
Long isthmus diameter	M	41	2.7	0.9
	F	16	2.6	1.1
Ring isthmus diameter	M	40	2.4	0.8
	F	15	2.1	0.7
Small isthmus diameter	M	40	3.2	0.9
	F	16	2.6	0.6
Index isthmus location	M	40	41.4	4.0
	F	15	37.6	3.6
Long distance to the isthmus	M	41	40.9	4.0
	F	16	36.4	3.5
Ring distance to the isthmus	M	40	35.3	3.5
	F	15	31.9	3.7
Small distance to the isthmus	M	40	32.5	4.2
	F	16	27.3	4.0
Index metacarpal length	M	40	69.3	4.3
	F	15	63.1	3.5
Long metacarpal length	M	41	67.8	4.6
	F	16	60.6	3.6
Ring metacarpal length	M	40	59.5	4.2
	F	15	54.0	3.0
Small metacarpal length	M	40	53.9	3.9
	F	16	48.9	3.5

Abbreviations: F, female; M, male.

between all metacarpals. We are not aware that this finding has been previously described. Furthermore, the absence of sex differences between the isthmus diameter of the long and ring metacarpals is another unique finding in this study.

The results of our study show that the majority of commercially available HCS that we tested fit well in the small finger metacarpal. This is likely because of its comparatively shorter length and wider intramedullary canal. The index metacarpal is particularly mismatched given its relatively narrow isthmus (2.6 mm), long length (67.3 mm), and corresponding long retrograde distance to the isthmus (40.2 mm). Evaluation of the available screw lengths shows that small caliber screws usually have a shorter range of lengths available. For instance, the 2.4-mm leading diameter of the DePuy

Synthes HCS has a maximum length of 40 mm. The average retrograde location of the isthmus for the index and long metacarpals are 40.2 and 39.5 mm, respectively. Eight other screw models between 2.3- and 2.6-mm leading diameter from seven other manufacturers have a maximum length of 34 mm available. This analysis shows that several of the manufacturers do not make screws in the smaller diameters that would be long enough in the index and long metacarpal for isthmus fixation without significantly countersinking the screw. This mismatch is more extreme in women who have on average smaller canal sizes.

To our knowledge, only one other study has used CT scans to evaluate the metacarpal bones in relation to intramedullary screw fixation. Ten Berg et al[12] used quantitative three-dimensional CT scans to show that the ring and small finger metacarpal head surface area (SA) and subchondral volume (SCV) occupied by countersunk 2.4- and 3-mm HCSs is minimal. 2.4-mm screws violated 10% of SA and occupied 4% of SCV, whereas 3-mm HCS violated 13% of SA and occupied 5% of SCV. Our study serves as a reference in the literature by analyzing native isthmus diameter, location, and hardware available for fixation.

As a limitation, we acknowledge that the study population approximated the gender breakdown for patients presenting with metacarpal fractures, though our patient population was somewhat older than most patients with metacarpal fractures. While the imaging diagnostics platform was standardized in contrast and brightness levels, there was variation in the thickness of cuts of sequences that may have affected measurement results. Furthermore, it is difficult to know whether the isthmus diameter was under- or overestimated with our standardized contrast and brightness levels without direct clinical correlation. We did not assess the biomechanics of headless screw fixation of metacarpal fractures in this study. Obtaining stability sufficient to allow early motion may or may not require reaching to or across the isthmus for some fractures, and this is a direction for future research. Finally, our study evaluated only seven manufacturers' commercially available HCSs that were publicly available. This does not account for several other manufacturers and updated product lines for the included manufacturer factors that may affect application and strength.

This study further characterizes metacarpal bony anatomy and sex differences. Surgeons should be mindful of the anatomical variations between metacarpals as this will influence appropriate screw fit and optimal screw lengths. Index and long metacarpals are at a particular risk of screw to isthmus length mismatch given the relatively long length and narrow isthmus diameter.

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None.

Conflict of Interest
None declared.

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